SESSION 4: BREAKOUT SESSION: BRIDGING THE GAP BETWEEN PREDICTABILITY AND CURRENT SKILL

Chair: **Jim Kinter**

Rapporteurs: **Dan Barrie, Heather Archambault**
(many thanks for excellent notes!!)

Breakout Discussion Summary

- Scientific questions - process
  - Model development and analysis of phenomena must be more closely related
  - Sub-seasonal is intersection of weather and climate time scales → crossover opportunity for NWP and climate prediction *practices*
    - Initial states, synoptic variability comingling with ENSO, PDO, MJO, etc. → Can the perspective and different approaches in terms of diagnostics/verification of NWP and climate people be used synergistically to address this problem?
    - Initialization issues are more important for sub-seasonal prediction than for seasonal prediction
  - May be better to just predict predictable components and then use those to predict impacts
  - This is a hard problem: A lot of the S2S predictability is on sharp gradients in space and time, which introduces many difficulties
  - Need to understand post-processing that's required

Breakout Discussion Summary

- Scientific questions - topics
  - Role of models' bias
  - Patterns of SST: ENSO, TAV, IOD, PDO, extratropical gradient zones
  - MJO → NAO, tornadoes & severe wx (NB: Can have high skill when MJO & NAO are quiet)
  - Stratospheric variability – full range, SSW and SPV, + QBO
    - How much of NAO predictability attributable to stratosphere vs. (tropical) troposphere?
  - PNA – is it predictable on subseasonal scales? Or is it noise?
  - Meridional mass circulation – Rossby waves → poleward mass transport → cold air outbreaks
  - Transient Rossby wave packets – potential for predicting extreme events; easy to mis-predict
  - Soil moisture & snow – Sweet spots; spring/summer focus (predictability rebound)
  - Soil moisture and veg. phenology → contribute to precip. and circulation forecast skill
  - Sea ice (not discussed much)
  - Ocean eddies → A-PBL and O-PBL forecast skill; resolved ocean eddies produce first-order different model; non-eddy-resolving ocean models are "essentially linear"
  - Stationary Rossby wave dispersion – potential for tracking precursors

Breakout Discussion Summary

- Modeling issues
  - Spatial resolution (and re-tuning methodology?)
  - Ocean-atmosphere coupling (eddy-resolving ocean?)
  - Lead-time dependent bias
  - Coupled DA and initialization (eddies too?)
  - Ensemble generation
  - Spread/skill relationship
  - Verification (flow dependence; precip., ensembles)
  - Benefit of MME (see below)
  - Reforecast ensemble size and length (e.g. issue of quality of initial states)

Breakout Discussion Summary

- Desires (no resource constraints):
  - Sufficiently high resolution in all Earth system components to resolve relevant processes *without parameterization*
  - Archive everything – all model output, including the heating and other RHS fields – at all time steps
  - Better reanalysis/hindcasts
  - Better obs – need to identify observing system gaps (time machine!)
  - Better initial conditions
  - More frequent initializations to look at flow dependent skill to make as many hindcasts as possible
  - Determine processes that lead to model biases and eliminate them

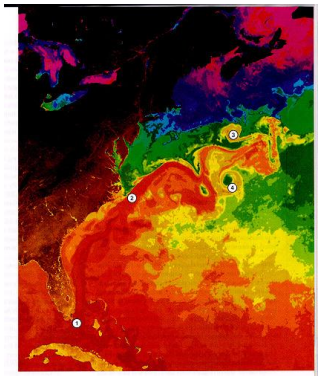
Breakout Discussion Summary

- Exploiting Multi-Model Framework
  - Run all models with same convective scheme, for example, and see what happens. Can be generalized to swapping model components
  - Test better ways to weight the NMME, e.g., flow-dependent weighting
    - Diagnose why some models are better for some phenomena
    - Understand which models are contributing the most to the phase space in terms of forecast scenarios for, say, a particular MJO event
    - More rigorously evaluate the difference in spread among the models
  - Role of compensating errors – uncover "hidden" aspects of the model
  - Perform coordinated case studies across NMME

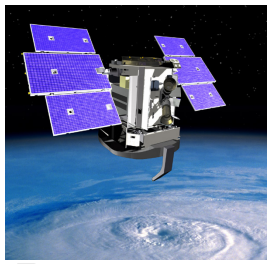
Breakout Discussion Summary

- Way forward (resource-constrained)
  - Prioritize model diversity vs. ensemble size. Need objective tests.
  - Determine optimal vertical resolution to get downward influence of stratosphere correct?
  - Is it important to maintain resolution of operational forecast models as forecasts go out in time?
  - Should we adapt the multimodel ensemble with an eye toward predicting extremes (i.e., not enough to know the ensemble mean – want the tails)?
    - How do you turn model ensemble relative frequencies into true probabilities?
  - How should CFS be run differently to address the S2S problem, given the anticipated ten-fold increase in computing power?
  - Legitimate to look to the private sector – seasonal predictions are being sold a year in advance

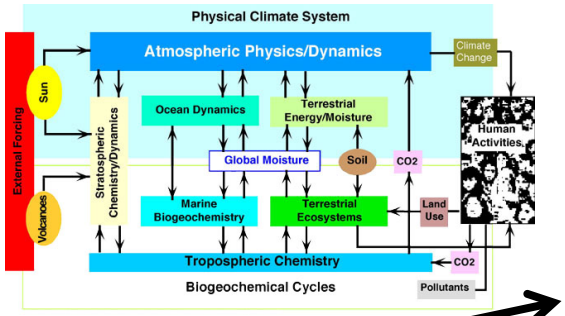
Balancing Demands on Resources



Atm + LSM
Ocn + SIM
Process-resolving



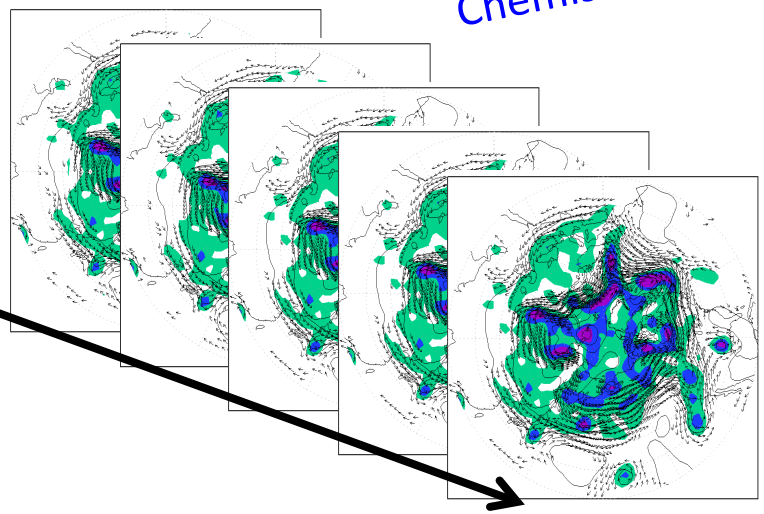
Data Assimilation
A, O, L, I Methods
Reanalysis Strategy



Resolution

Data and HPC Resources

Complexity
Predicting Ocean?
Aerosols?
Chemistry?



Ensemble size
Resolve full PDF
Including Extremes

Focus Questions

1. What are the most important scientific questions that need to be answered to bridge the gap between current and potential skill for sub-seasonal timescales?
2. Without resource limits, how would you approach answering those questions?
3. How would a multi-model ensemble re-forecast contribute to answering those questions?
4. Within resource limits, what system improvements (e.g. horizontal resolution, stratospheric vertical resolution, ensemble size, initialization) are most likely to cost-effectively improve sub-seasonal skill?

The Four Questions

- Why is this night different from all other nights?
- On all other nights we eat leavened and unleaved bread. Why on this night do we eat only matzoh?
- On all other nights we eat all vegetables. Why on this night do we eat only bitter herbs?
- On all other nights we don't dip our food even once. Why on this night do we dip twice?
- On all other nights we eat sitting or reclining. Why on this night do we only recline?

מַה־נִּשְׁתַּנָּה הַלַּיְלָה הַזֶּה מִכָּל־
הַלֵּילוֹת?

שֶׁבְּכָל־הַלֵּילוֹת אֲנוּ אוֹכְלִין חָמֵץ
וּמַצָּה; הַלַּיְלָה הַזֶּה, כֻּלּוֹ מַצָּה.

שֶׁבְּכָל־הַלֵּילוֹת אֲנוּ אוֹכְלִין שְׁאָר
יְרָקוֹת; הַלַּיְלָה הַזֶּה, מָרוֹר.

שֶׁבְּכָל־הַלֵּילוֹת אֵין אֲנוּ מַטְבִּילִין
אֲפִלּוּ פַּעַם אֶחָת; הַלַּיְלָה הַזֶּה,
שְׁתֵּי פְעָמִים.

שֶׁבְּכָל־הַלֵּילוֹת אֲנוּ אוֹכְלִין בֵּין
יוֹשְׁבִין וּבֵין מְסֻבִּין; הַלַּיְלָה הַזֶּה,
כֻּלָּנוּ מְסֻבִּין.

The New 10 Plagues:

Top Ten S2S Prediction Problems in NMME Models

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Topics

- Predicting the predictors
  - Role of models' bias
    - Predictability is a model-based quantity; models are imperfect; possible non-linear interaction between mean bias and predictability (and prediction skill)
  - SST – ENSO, TAV, IOD, PDO, extratropical gradient zones, in- and out-of-phase concurrency of different SST patterns
  - MJO – largest compact phenomenon on sub-seasonal time scale
  - Stratospheric variability
    - Sudden Stratospheric Warming and Strong Polar Vortex – extremes of stratospheric boreal winter circumpolar circulation
    - SSW occurs infrequently → forecast of opportunity
    - QBO – very predictable, surface impact is small and not known to be predictable
    - Is there a preferred time scale for lead (lag) time? → cycle from surface disturbance to upward propagating wave activity to finite amplitude polar vortex perturbation to surface signal
  - PNA – is it predictable on subseasonal scales? Or is it noise?
  - Meridional mass circulation – Rossby waves → poleward mass transport → cold air outbreaks
  - Transient Rossby wave packets – potential for predicting extreme events, but easy to mis-predict
  - Soil moisture and snow – Sweet spots; focus on spring and summer seasons (predictability rebound)
  - Sea ice

Topics

- Predicting the impact of the predictors
  - Bias plays a role here also
  - ENSO – modulates sub-seasonal signals?
  - IOD - Asian monsoon, east African rainfall
  - MJO → NAO, tornadoes & severe wx
    - Can have high skill when MJO & NAO are quiet
  - SSW → NAO
    - May be better to just predict NAO – higher S/N; more general: predictable components
  - How much of NAO predictability is attributable to stratosphere and how much to (tropical) troposphere?
  - Soil moisture and veg. phenology → contribute to precip. and circulation forecast skill
  - Ocean eddies → A-PBL and O-PBL forecast skill; resolved ocean eddies produce first-order different model; non-eddy-resolving ocean models are "essentially linear"
  - Stationary Rossby wave dispersion – potential for tracking precursors

Process

- Model development vs. model phenomena analysis are not sufficiently closely related
- Sub-seasonal is intersection of weather and climate time scales → crossover opportunity for NWP and climate prediction *practices*
- Initialization issues are more important for sub-seasonal prediction than for seasonal prediction
- Post-processing and understanding the post-processing that's required would be useful
- May be better to just predict NAO
  - Higher signal/noise
  - More generally: use predictable components
- A lot of the predictability we're talking about is on sharp gradients in space and time, which introduces many difficulties

Focus Questions

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Modeling Issues

- Spatial resolution (and re-tuning methodology?)
- Ocean-atmosphere coupling (eddy-resolving ocean?)
- Lead-time dependent bias
- Coupled DA and initialization (eddies too?)
- Ensemble generation
- Spread/skill relationship
- Verification (flow dependence; precip., ensembles)
- Benefit of MME
- Reforecast ensemble size and length (quality of initial states)

No Resource Constraints

- Extremely high resolution to resolve relevant processes without parameterization
- Archive everything – all model output, including the heating and other RHS fields – at all time steps
- Better reanalysis/hindcasts (time machine!)
- Better obs
- Better initial conditions
- More frequent initializations to look at flow dependent skill to make as many hindcasts as possible
- What processes lead to model errors?

Focus Questions

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2. Without resource limits, how would you approach answering those questions?
3. **How would a multi-model ensemble re-forecast contribute to answering those questions?**
4. Within resource limits, what system improvements (e.g. horizontal resolution, stratospheric vertical resolution, ensemble size, initialization) are most likely to cost-effectively improve sub-seasonal skill?

Suggestions

- Run all models with same convective scheme, for example, and see what happens
  - A model can be bad because its convective scheme is bad
  - Usual approach is to make modifications to the convective scheme, rather than change it entirely
  - Changing model physics can lead to dramatically different results
    - Even using a regional scope to understand regional scope would be very valuable
    - Same large-scale flow, but different physics configurations (remove global flow dependence)
- Exploit NMME by doing diagnostics by seeing which model does what better in what phenomena
  - Such a comparison can drive improvement of your own model
  - Why are some models better for some phenomena?
- Test better ways to weight the NMME
  - Dynamical weighting may increase skill
- Role of compensating errors – uncover "hidden" aspects of the model
- Perform coordinated case studies
- Spread difference among the models
- Understand which models are contributing the most to the phase space in terms of forecast scenarios for, say, a particular MJO event
- Taking equal weighting works the best
  - Is it worth trying to improve the weighting beyond equal weighting? Is this a valid science question?
- S2S: Initial states, synoptic variability comingling with ENSO, PDO, MJO, etc.
  - Can the perspective of NWP and climate people be used synergistically to address this problem?
  - Different approaches in terms of diagnostics/verification

Focus Questions

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Suggested System Improvements

- Which is more important - model diversity or ensemble size?
  - Not definitive – sometimes model diversity is more important, sometimes ensemble size is more important
- How many vertical levels do we need to get the downward forcing of stratosphere correct?
- Is it important to preserve the higher resolution of operational forecast models as forecasts go out in time?
  - Some centers do this, and some do not
    - CFS doesn't change resolution
  - For NWP, have a discontinuity in the climate that occurs when the horizontal resolution becomes degraded in the forecast
- Should we adapt the multimodel ensemble with an eye toward predicting extremes (i.e., not enough to know the ensemble mean – want the tails)?
- How do you turn model ensemble relative frequencies in to true probabilities?
- Ocean dynamics are not captured at the resolution of the models
  - Issue of stochastic physics vs. stochastic dynamics
-
- Worth addressing whether CFS should be run differently to address the S2S problem, given the ten-fold increase in computing power?
- Legitimate to look to the private sector – seasonal predictions are being made a year in advance
  - They perform direct comparison with CPC
  - Something we should be aware of